

Beam Diagnostics & Beam Studies at HINS / MDB

Vic Scarpine - Fermilab

Project X Collaboration Meeting

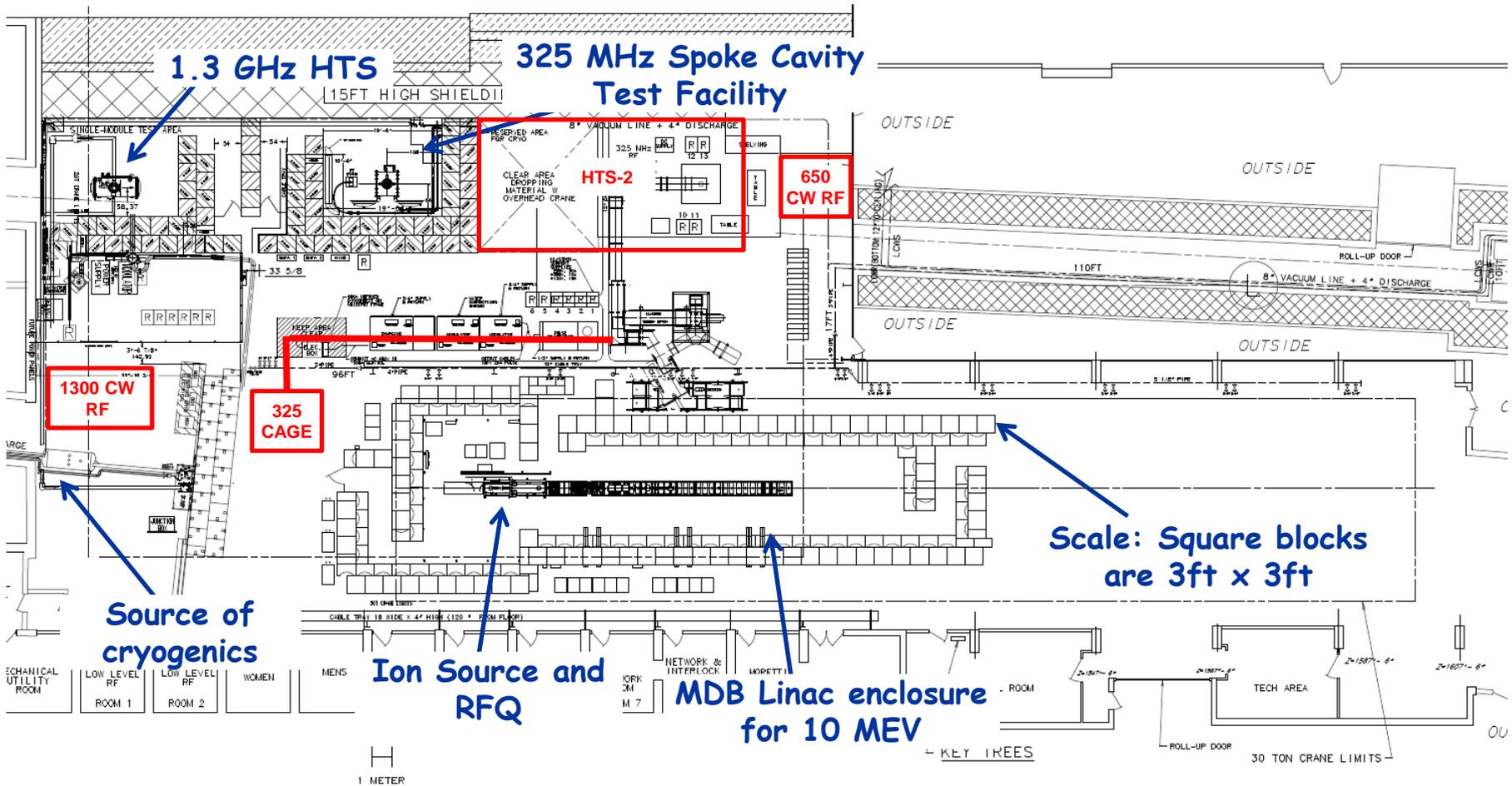
13 Apr 2011



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- Motivation
 - HINS Parameters
 - HINS Measurements to Date
 - Beam Diagnostic Projects
 - Collaborations
 - Goals and Timelines
 - Conclusions

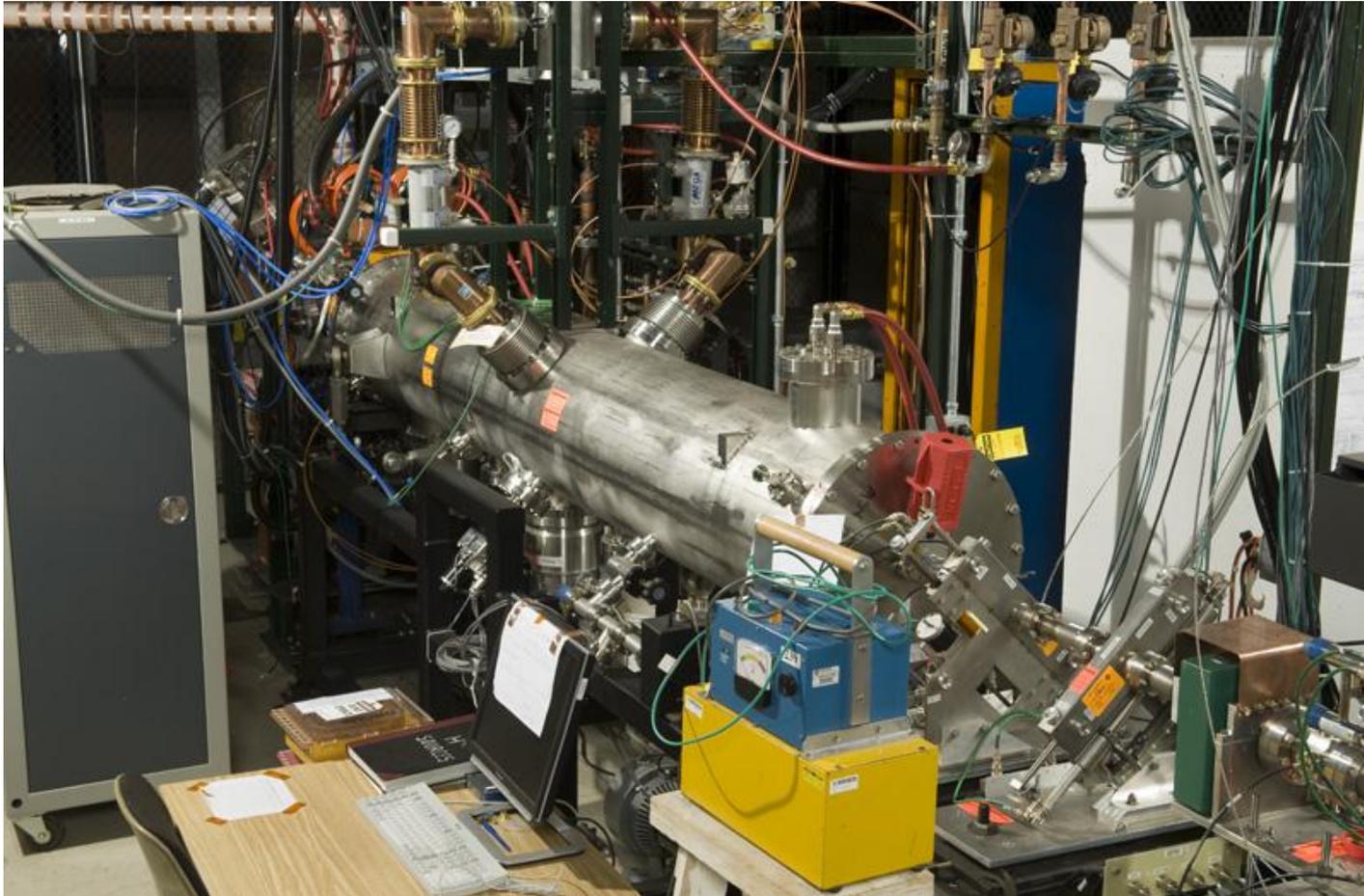


- The Meson Detector Building (MDB) Test Facility (formerly known as HINS – High Intensity Neutrino Source) ultimately comprises:
 - A shielded beam line enclosure with first proton, then H^- , pulsed 1% duty factor, 3 millisecond beam up to 10MeV
 - For Project X 325 MHz superconducting spoke cavity beam tests
 - For Project X chopper tests
 - For Project X H^- beam instrumentation development
 - Shielded enclosures and RF power systems for testing individual, jacketed 1.3 GHz, 650 MHz, and 325 MHz superconducting RF cavities (no beam)
 - For ILC
 - For Project X



MDB Test Facility

325 MHz Pulsed RFQ





Particle	H+ then H-	
Nominal Bunch Frequency/Spacing	325 3.1	MHz nsec
Particles per Pulse	37.5 *	E13
Pulse Length	3/1	msec
Average Pulse Current	~ 20	mA
Pulse Rep. Rate	2.5/10	Hz
Bunch Current	32	mA
Bunch Intensity	6.1 98	E8 pCoul

*** full un-chopped 3 msec pulse at klystron-limited 20 mA**

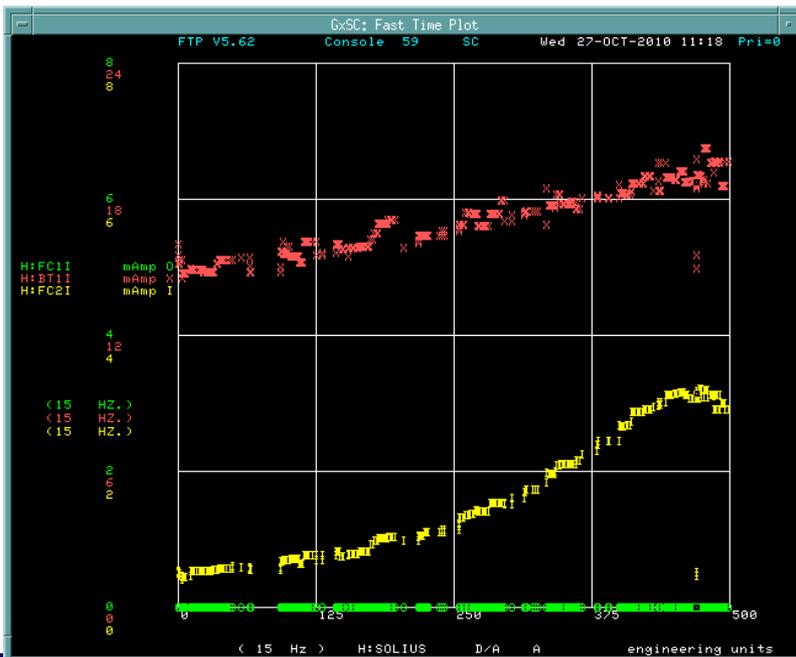
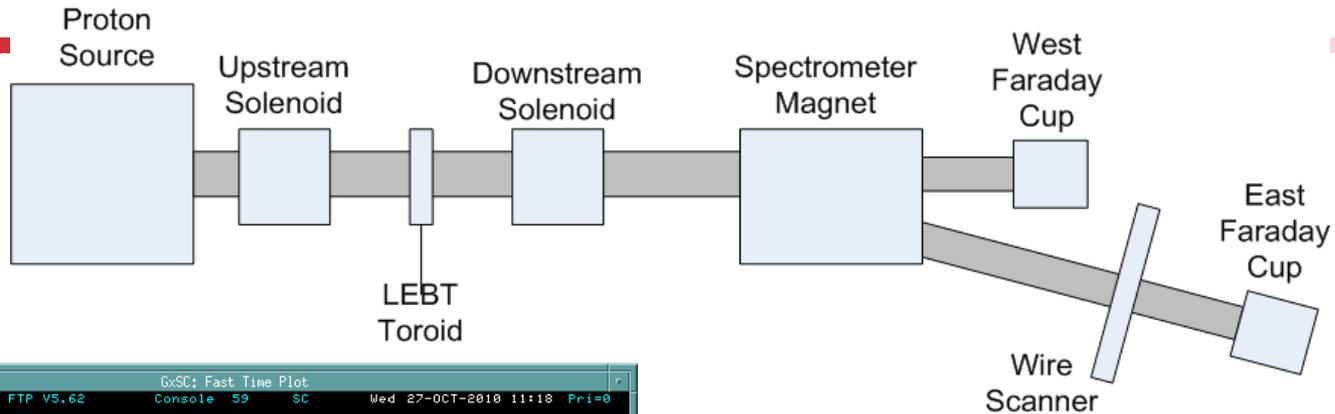


Initial Proton Source and RFQ Beam Measurements



- First proton beam through RFQ in Spring 2010
- Beam parameters:
 - Ion source (protons): 500 usec @ 1 Hz
 - RF: 50 usec @ 0.5 Hz
 - RFQ operated without cooling
- Ion Source Toriod ~ 15-20 ma
 - <50%?? protons; >50%?? other (H2+, H3+)
 - Ion source species are being measured
- RFQ Output Toriod Current ~ 3-4 ma
 - Possible beam loss after RFQ but before toroid
- *Basic diagnostics line to make transverse profiles and energy measurements*

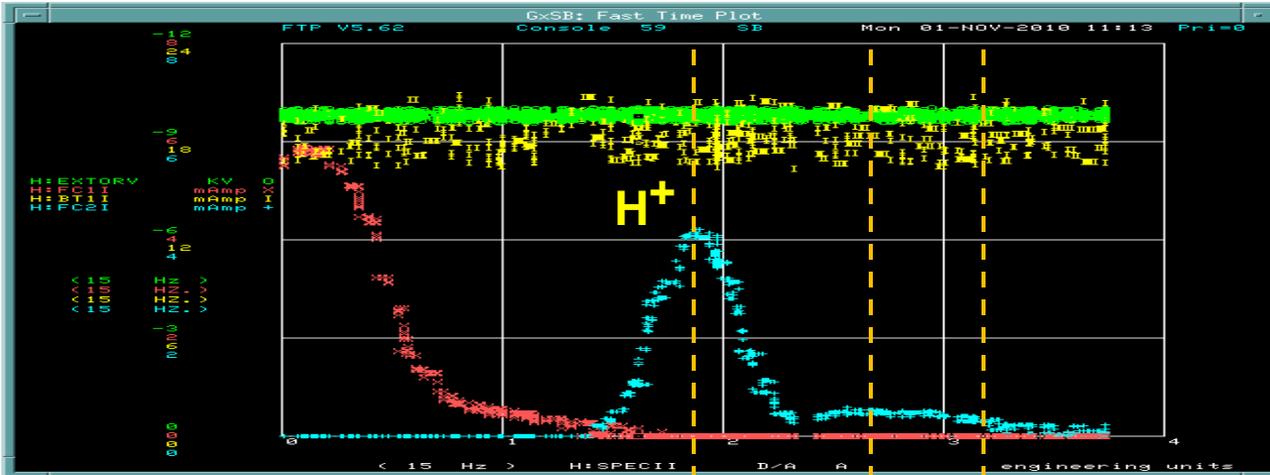
Proton Source Test Setup



LEBT Toroid

East Faraday Cup

- Optimize Upstream solenoid to transmit Max protons to east Faraday cup
- spectrometer set for protons
 - Up solenoid → 470 A



170 A

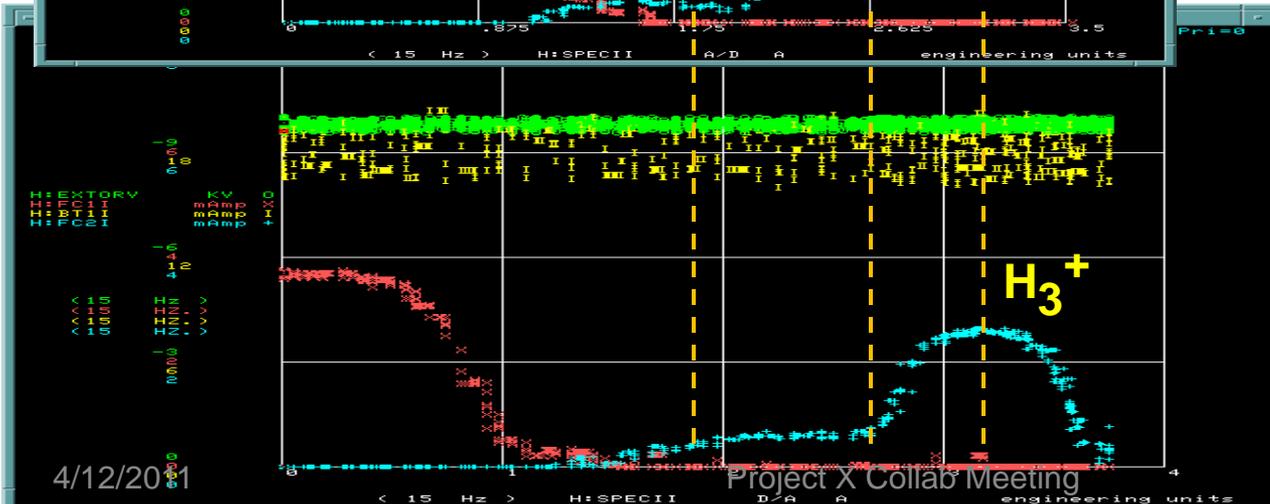
Horz scales aligned

- Green – Source Extractor Voltage
- Yellow – LEBT Toroid Current
- Red – West Faraday Cup (straight ahead)
- Blue – East Faraday Cup (bend)



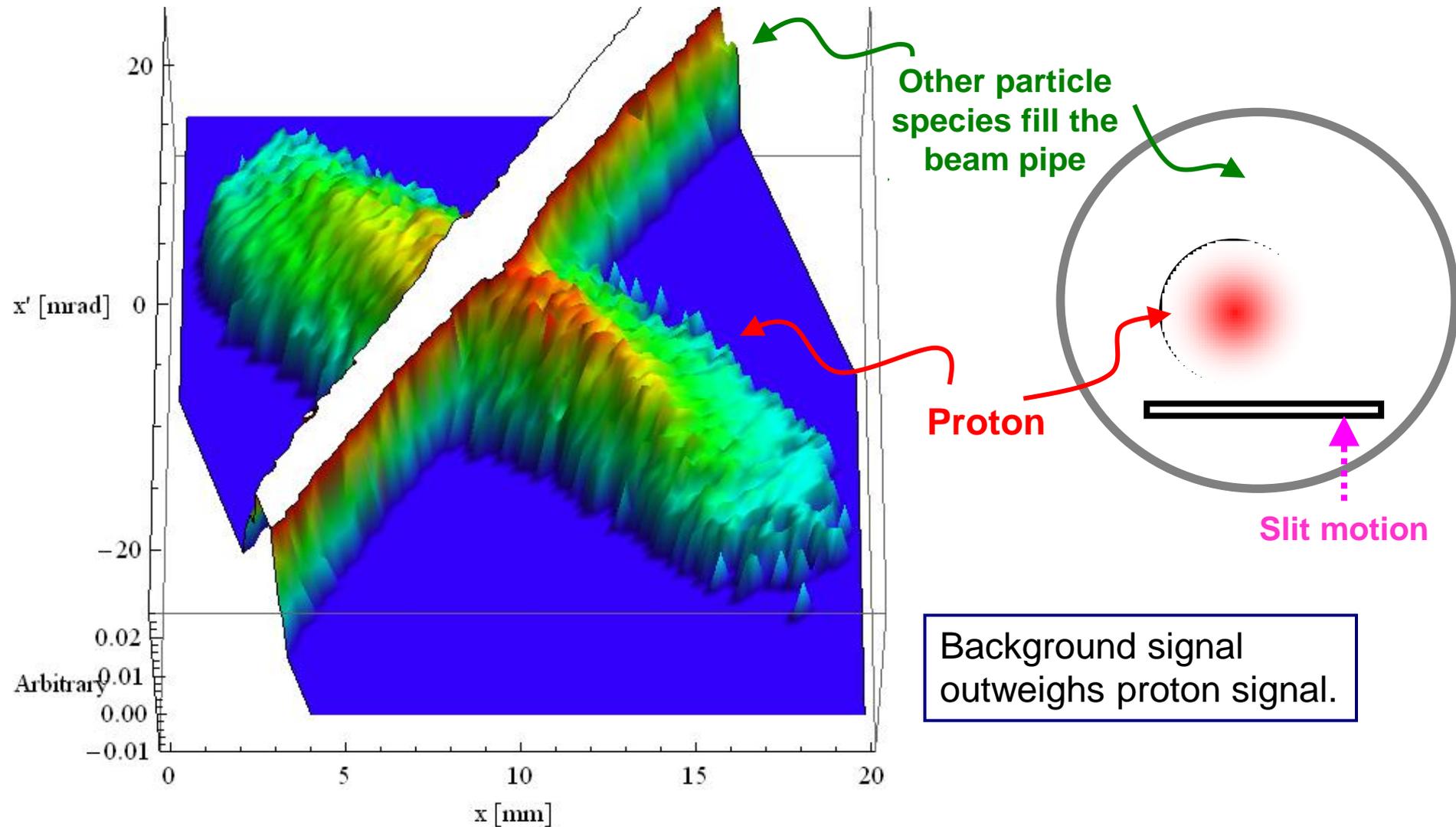
275 A

- Downstream solenoid optimized for each species
- Upstream solenoid fixed at 470 A

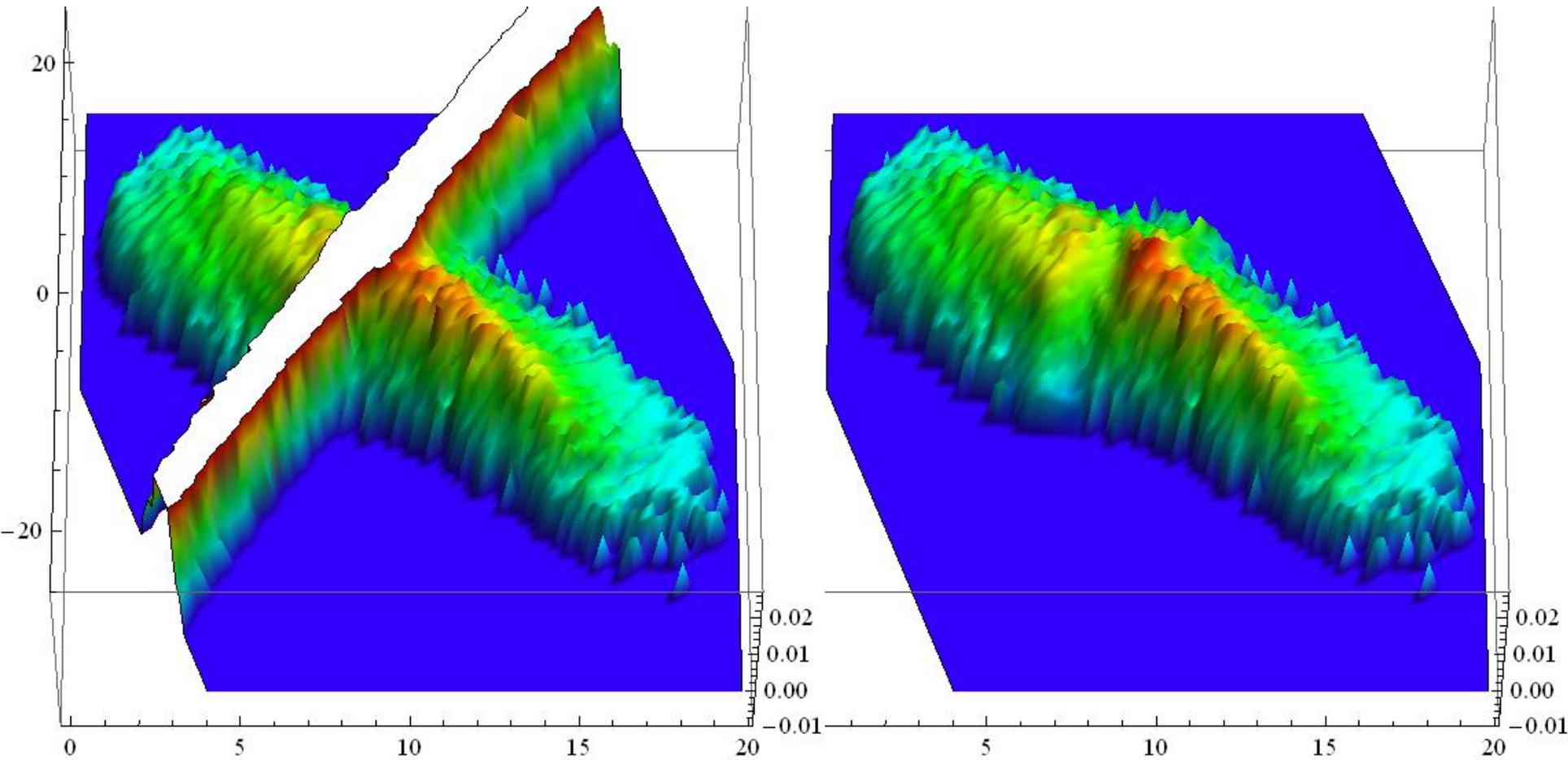


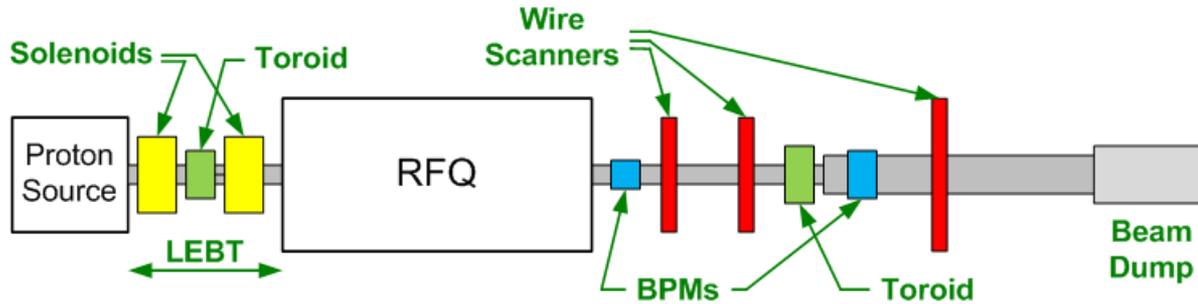
335 A

Proton Source Slit-WS Emittance Measurement



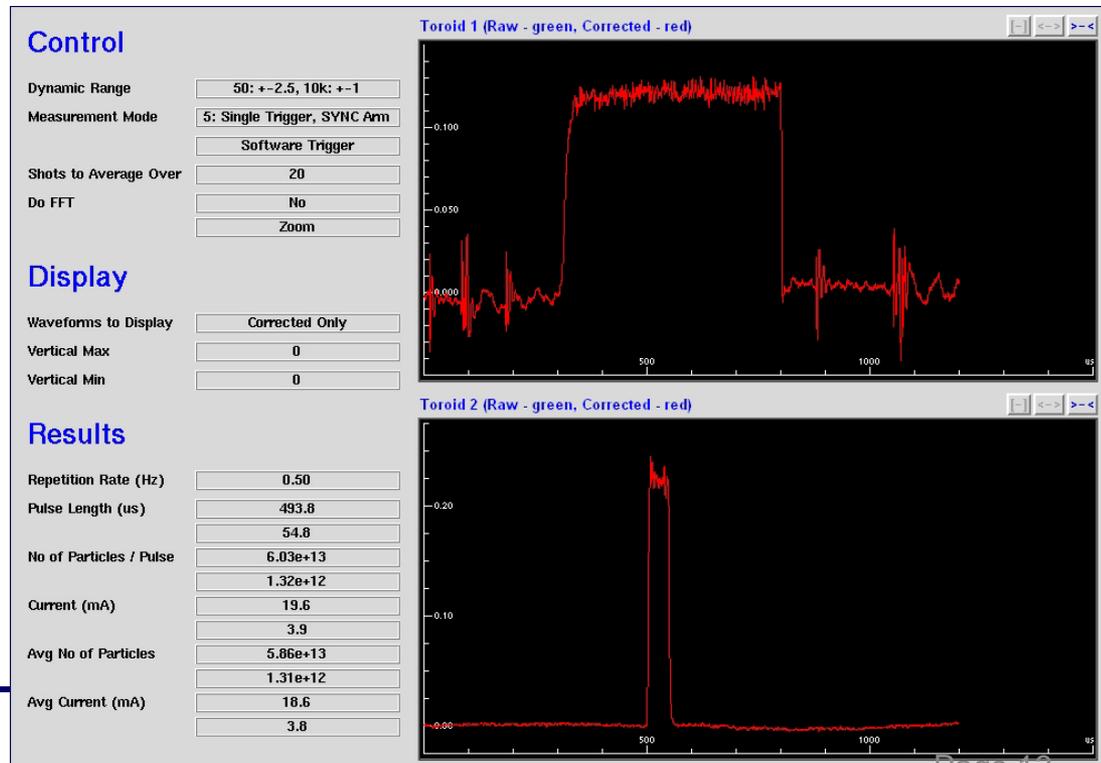
Signal Cleaning





Initial Diagnostics Line

Initial Beam Currents

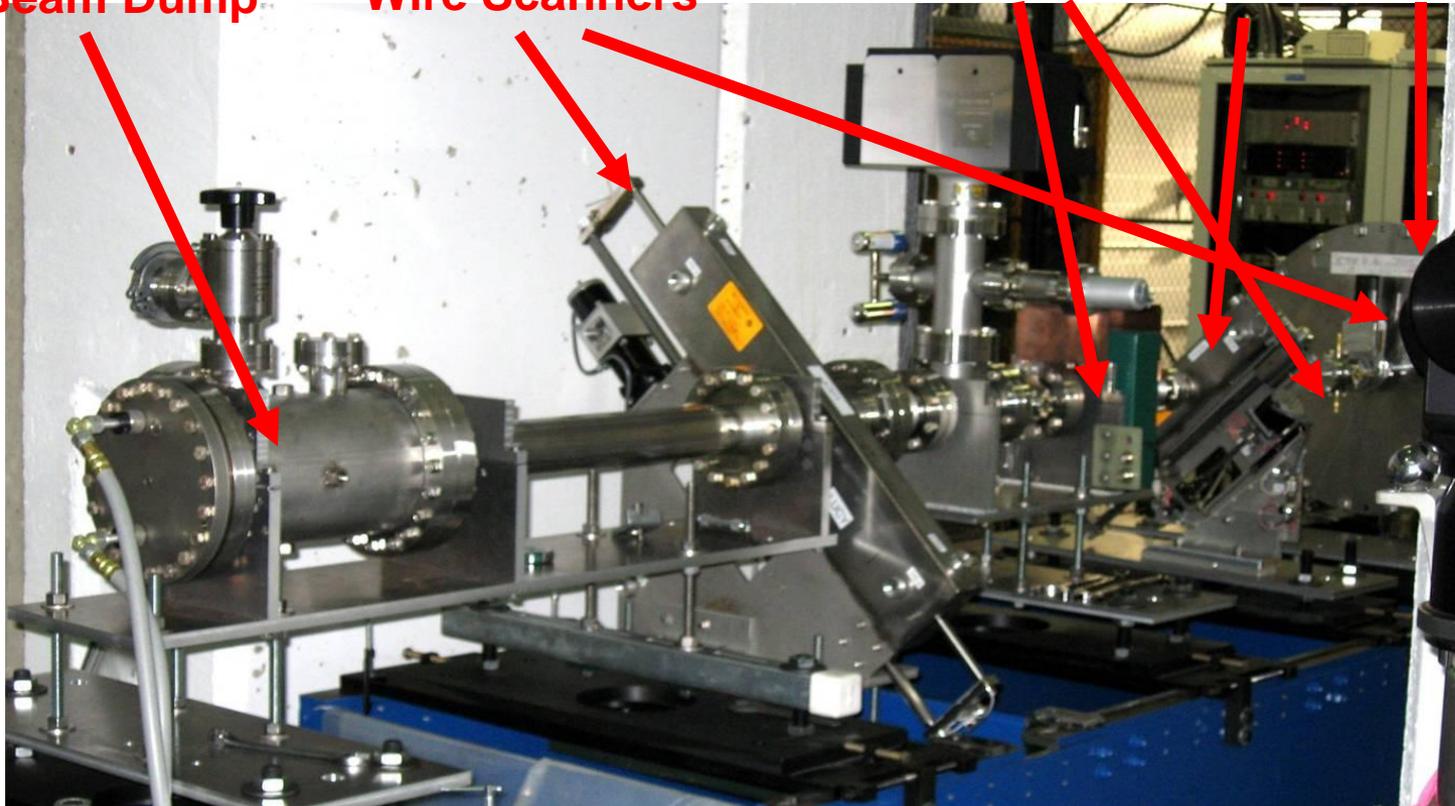


Initial RFQ Beam Diagnostics



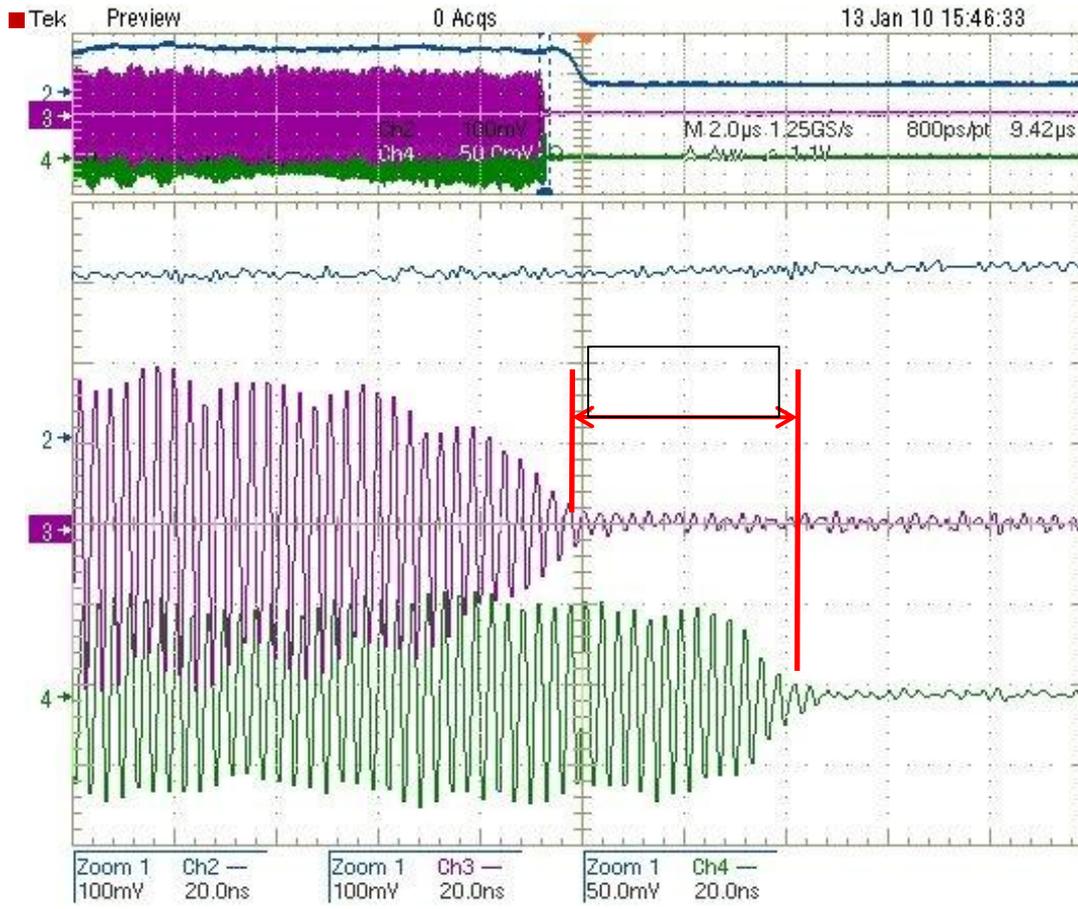
The HINS linac was equipped with a reconfigurable, movable diagnostics station at the end of the linac

Beam Dump **Wire Scanners** **BPMs** **Toroid** **RFQ**



RFQ Energy Measurement – First Beam on 1/13/2010

Project X
Project X



Signals from toroid and two BPM buttons, all downstream of the RFQ

Upper display: 2 μ sec/div

Lower display: 20 nsec/div

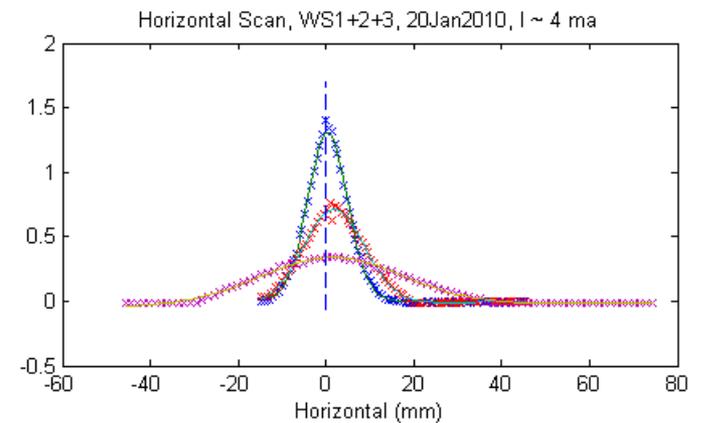
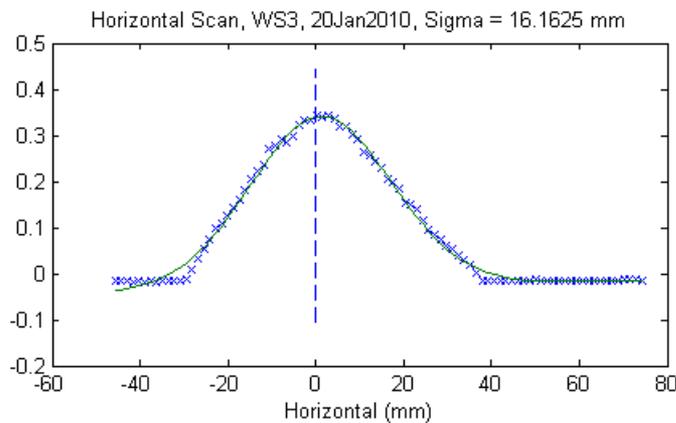
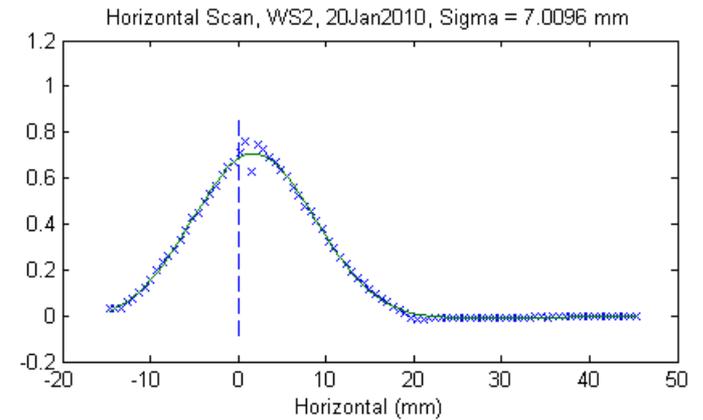
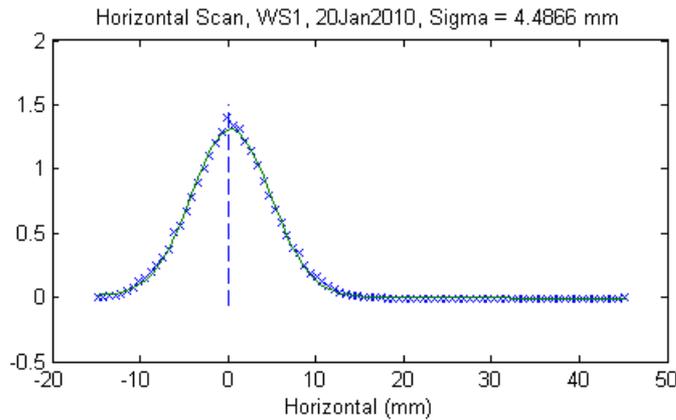
Lower display shows the 44nsec delay expected for transit of 2.5 MeV beam between the BPM two buttons separated by 0.96 meters

Beam current is about 3 mA

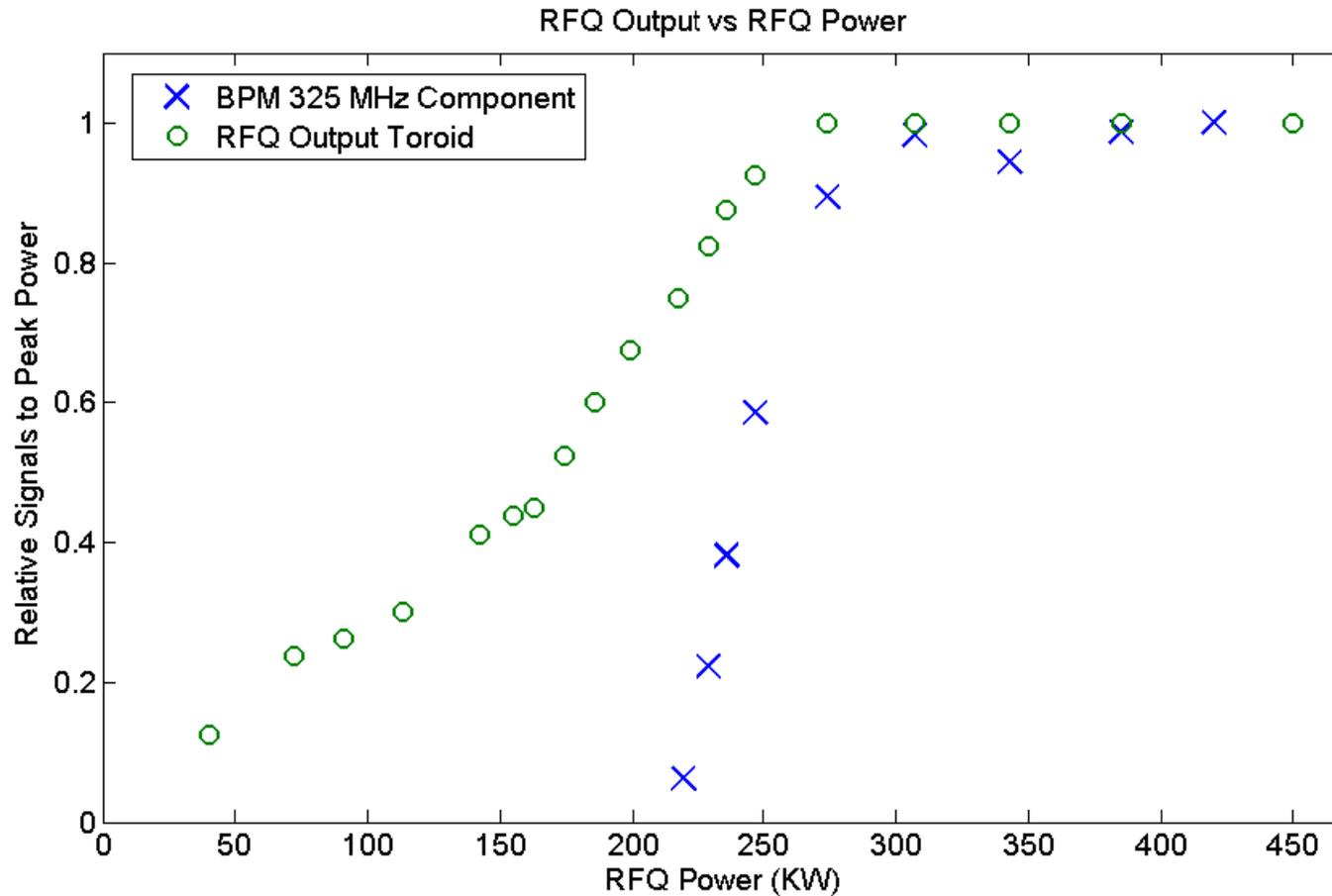
Early 2.5 MeV Beam Profiles – Horizontal at 4 mA



Note: Beam loss after first wire scanner



Relative RFQ Output Beam vs. RF Power



Next Iteration of RFQ Beam Measurements



- Initial measurements suffered from RFQ water leak problems
 - RFQ limited to 50 μ sec pulses
 - RFQ has been repaired and reinstalled at the Meson test facility
- Initial RFQ measurements suffered many issues
 - No longitudinal measurements → FFC and BSM
 - No transverse emittance measurements → Quad-Wire, Slit-Wire
 - Energy measurement was not precise → spectrometer magnet
 - RFQ transmission efficiency not measured
 - Toroid not close enough to RFQ output
- New diagnostics line has been install
 - Reconfigurable
 - Space for R&D projects

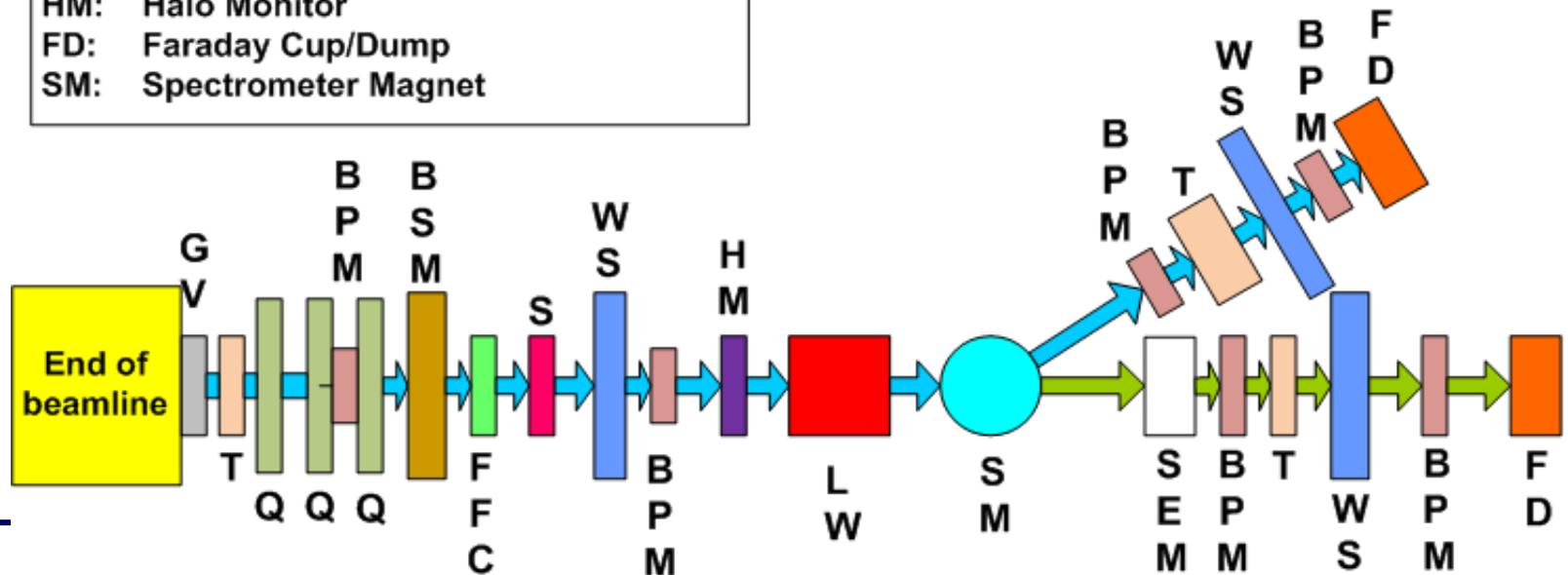
Advanced HINS Diagnostics Line

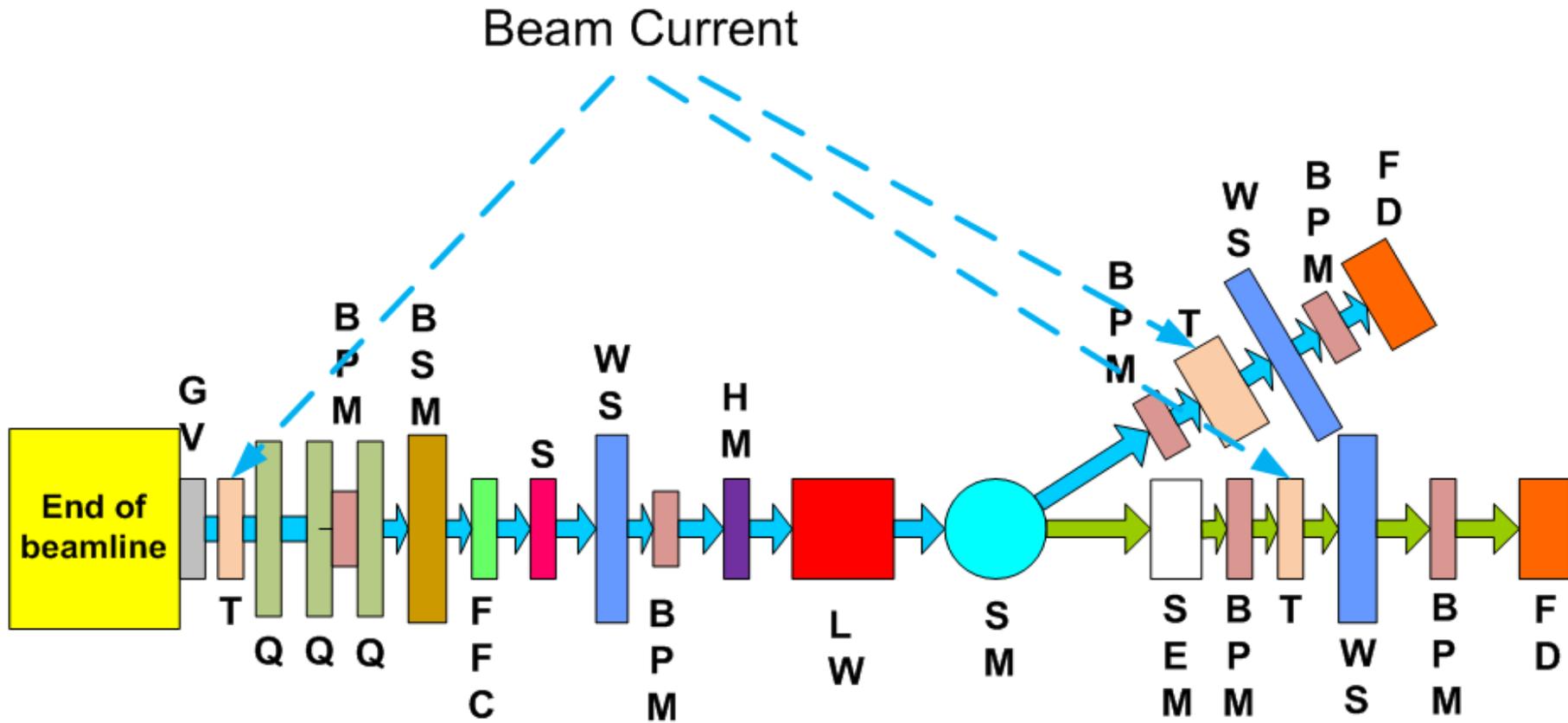


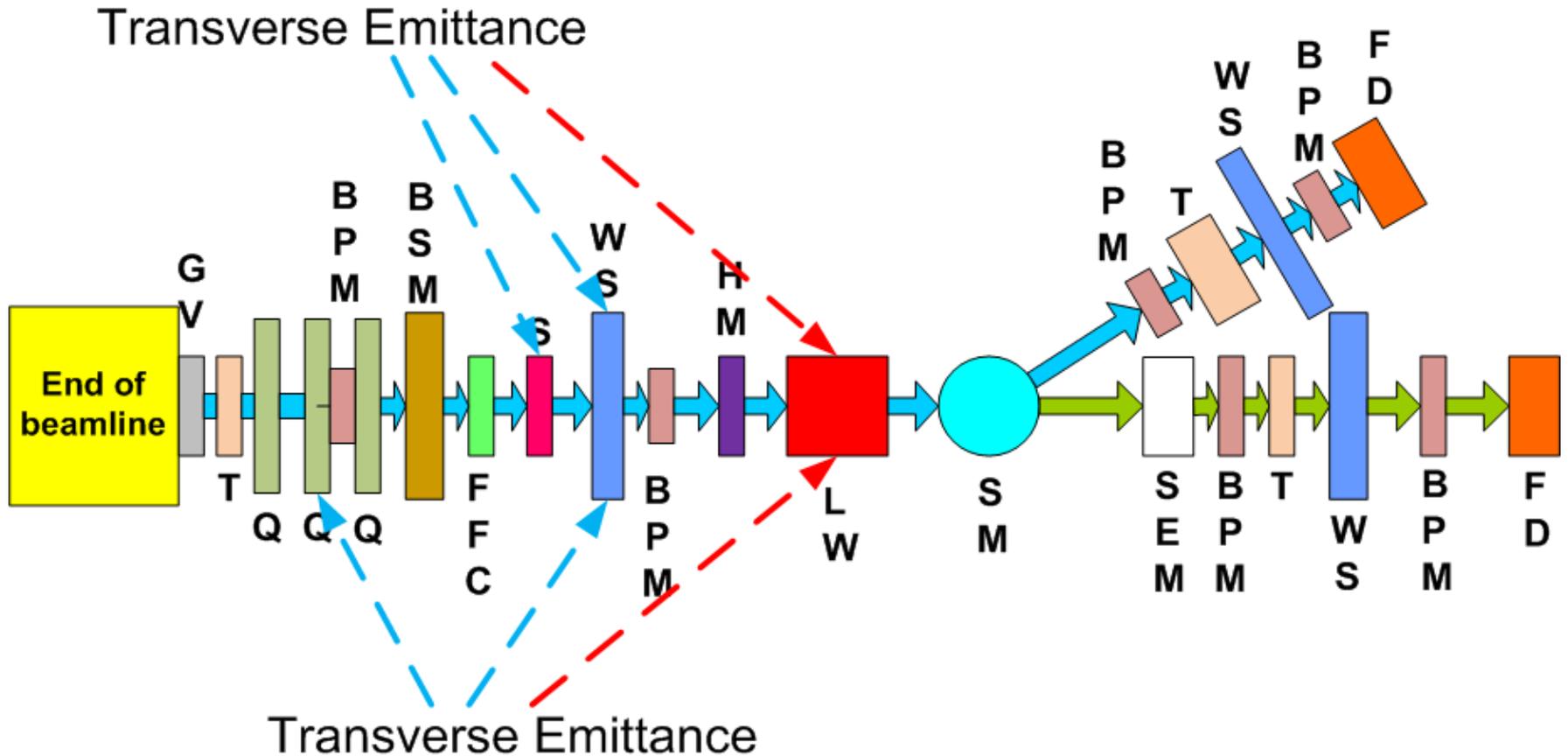
- T: Toroid
- GV: Gate Value
- Q: Quadrupole
- LW: Laser Wire
- SEM: Secondary Emission Monitor
- BPM: Beam Position Monitor
- WS: Wire Scanner
- S: Horz and Vert Slits
- BSM: Bunch Shape Monitor (Longitudinal)
- FFC: Fast Faraday Cup
- HM: Halo Monitor
- FD: Faraday Cup/Dump
- SM: Spectrometer Magnet

Advanced HINS Diagnostics Line
V 1.0
May 19, 2010

➡ H^- Beam
➡ H^0 Beam or H^- Beam

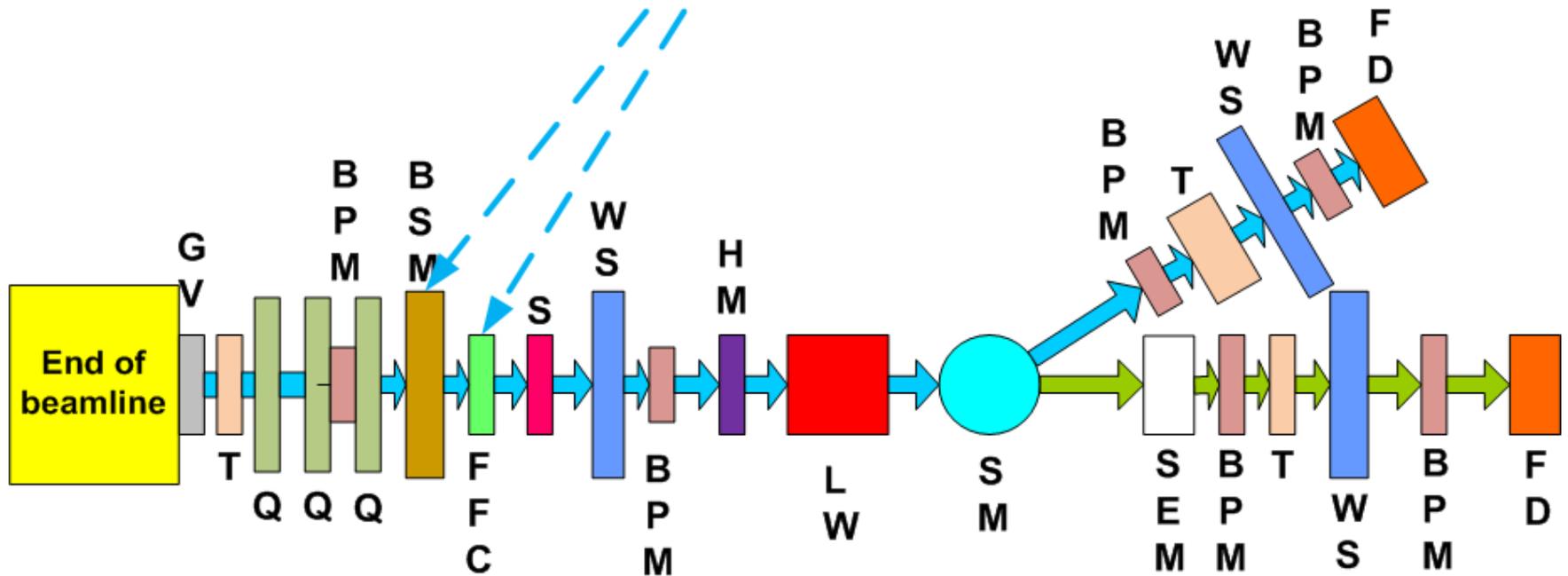






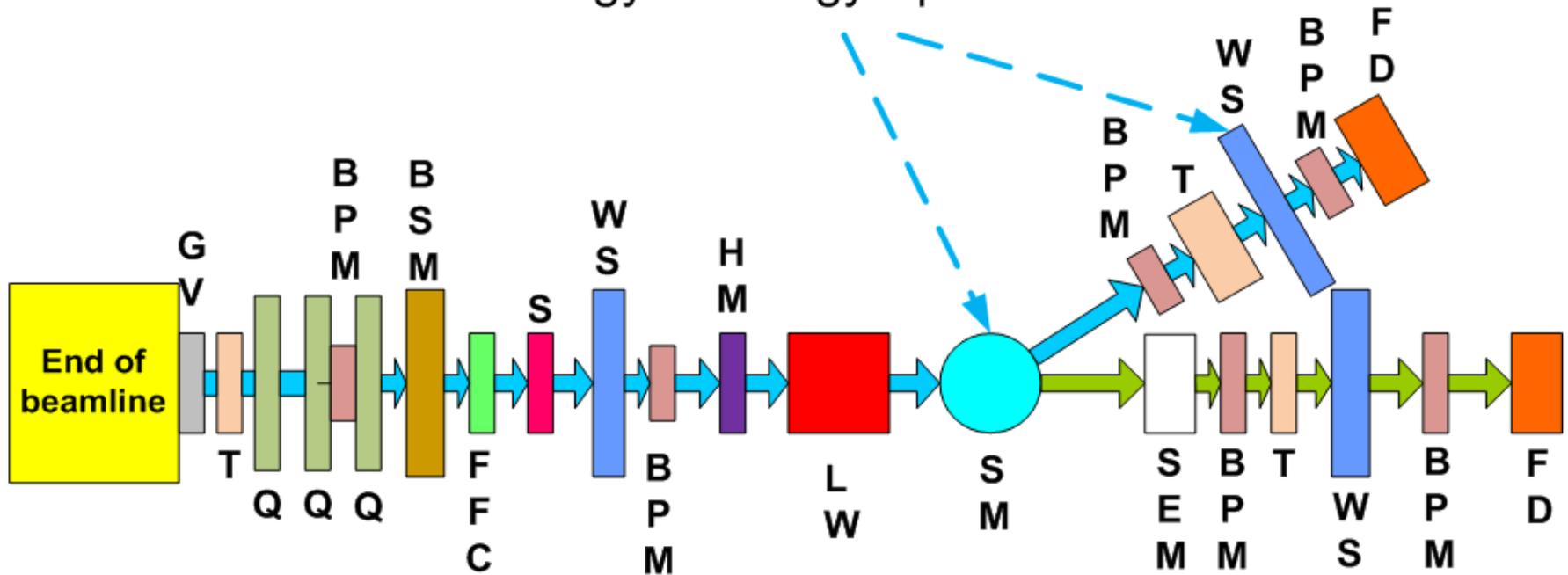


Longitudinal Bunch Shape





Energy & Energy Spread

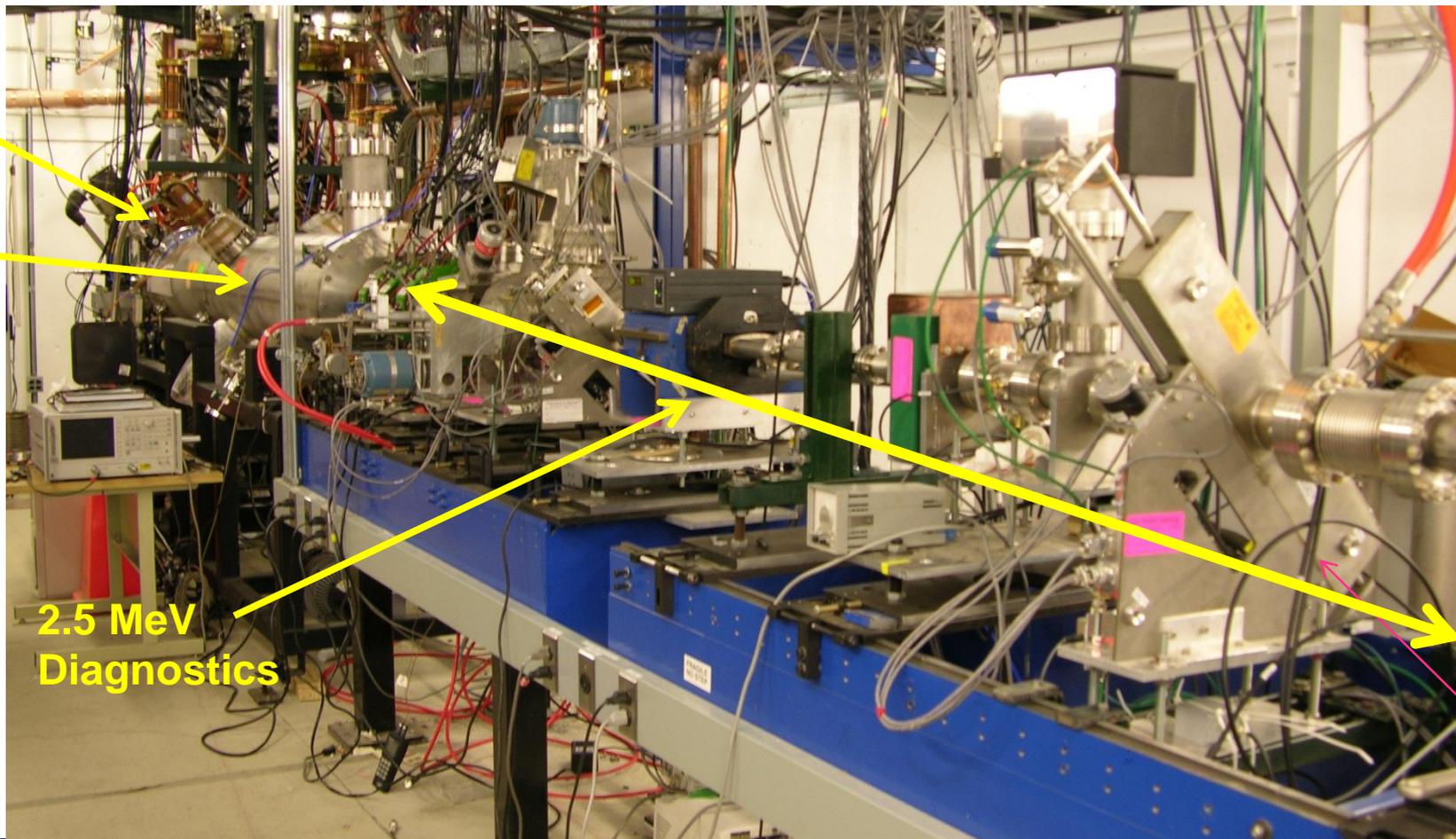


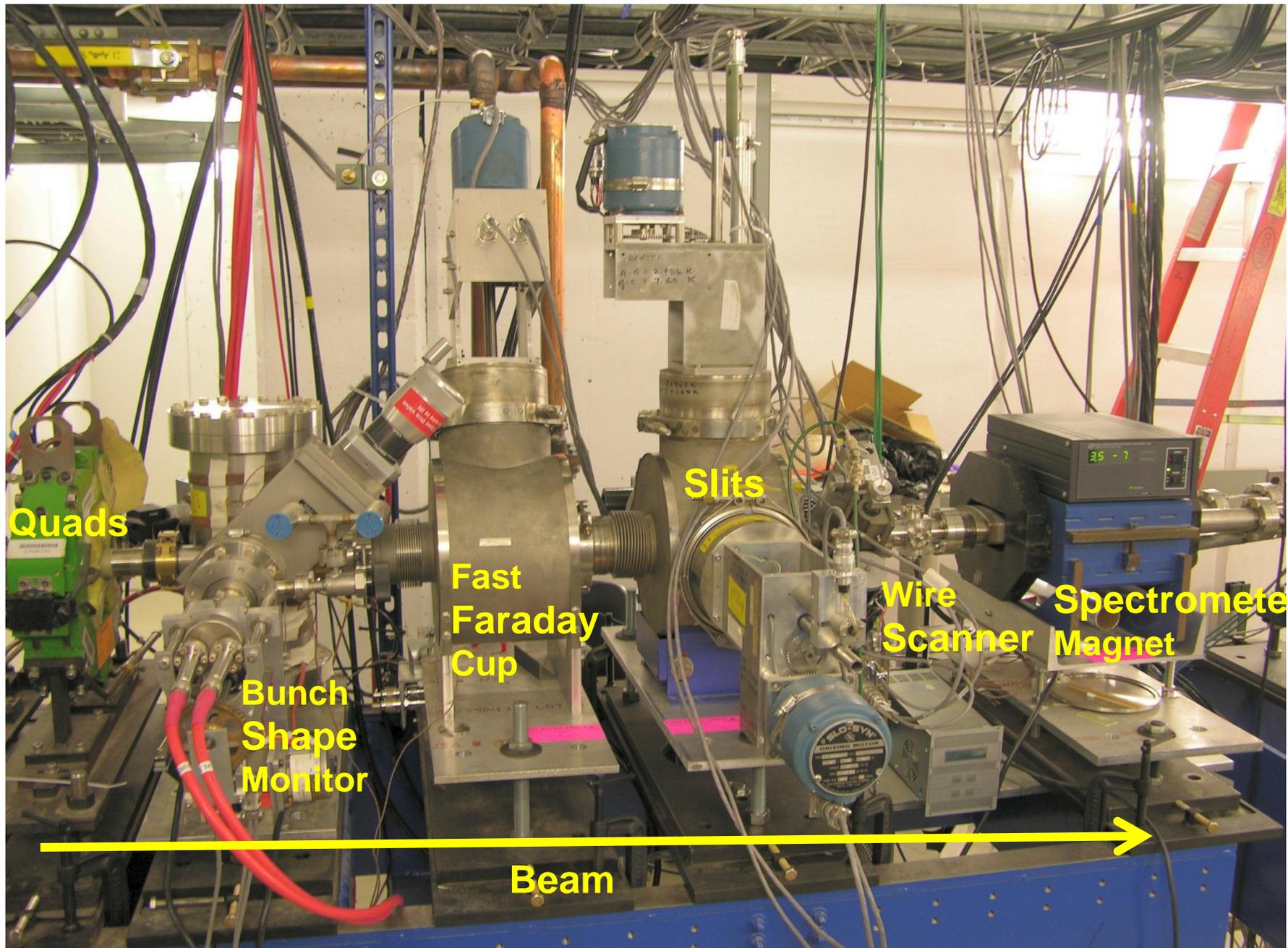


Source /LEBT

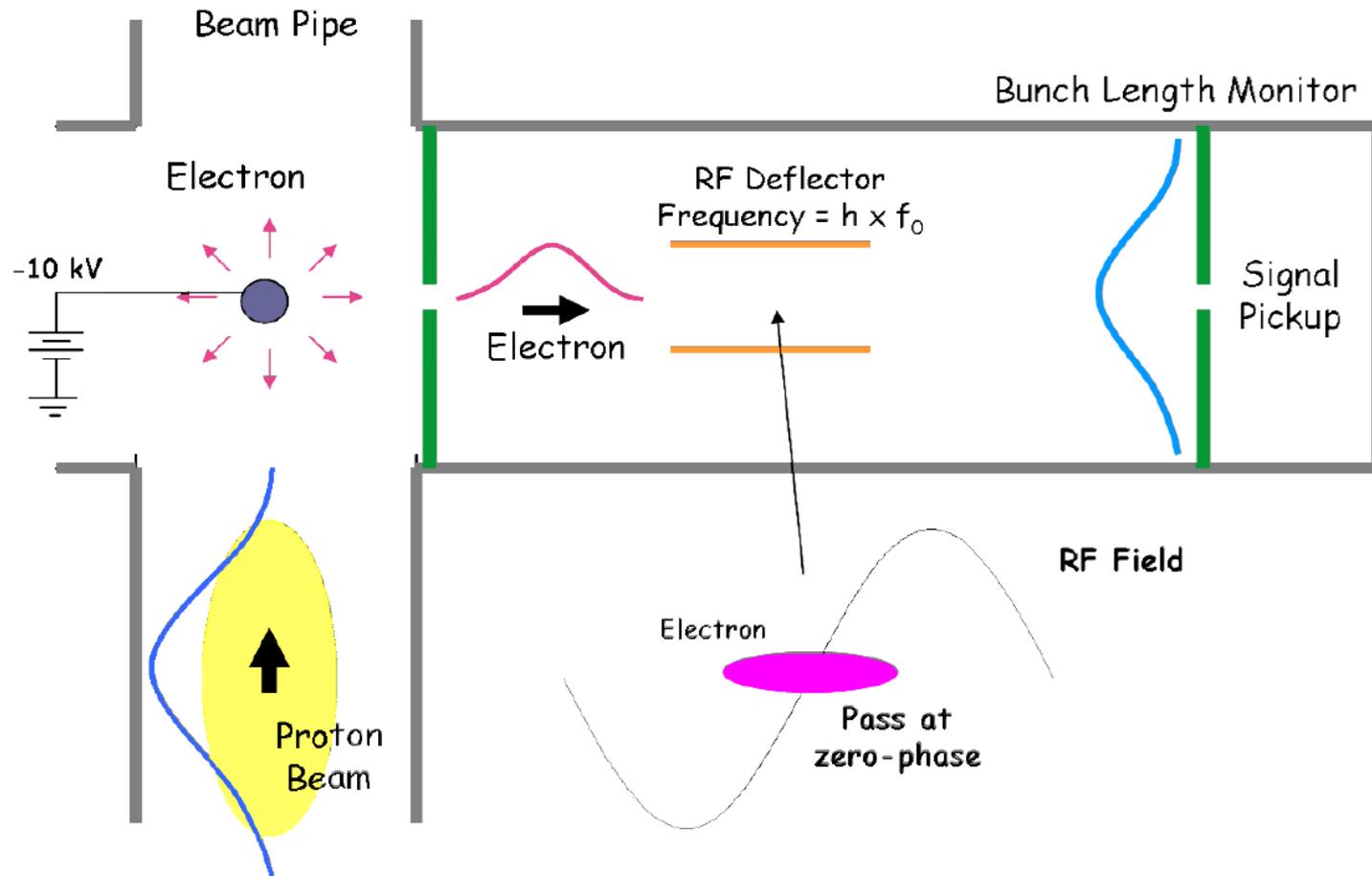
RFQ

**2.5 MeV
Diagnostics**





Longitudinal Bunch Shape Monitor





- *Transverse Diagnostics*
 - Laser Transverse Profile Monitor*
 - Ionization Profile Monitors
 - Electron Wire Transverse Profile Monitor
- *Longitudinal Diagnostics*
 - Wire Longitudinal Profile Monitor*
 - Laser Longitudinal Profile Monitor*
 - Broadband Faraday-cup*
- Halo Monitoring – transverse and longitudinal
 - Vibrating wire* - *from Bergoz Instrumentation*
 - Laser wire*
- MEBT Emittance station
 - Slit-collector*
 - Laser Slit*

* *Project X related instrumentation to be tested at HINS*

Project X Beam Diagnostics Collaborations

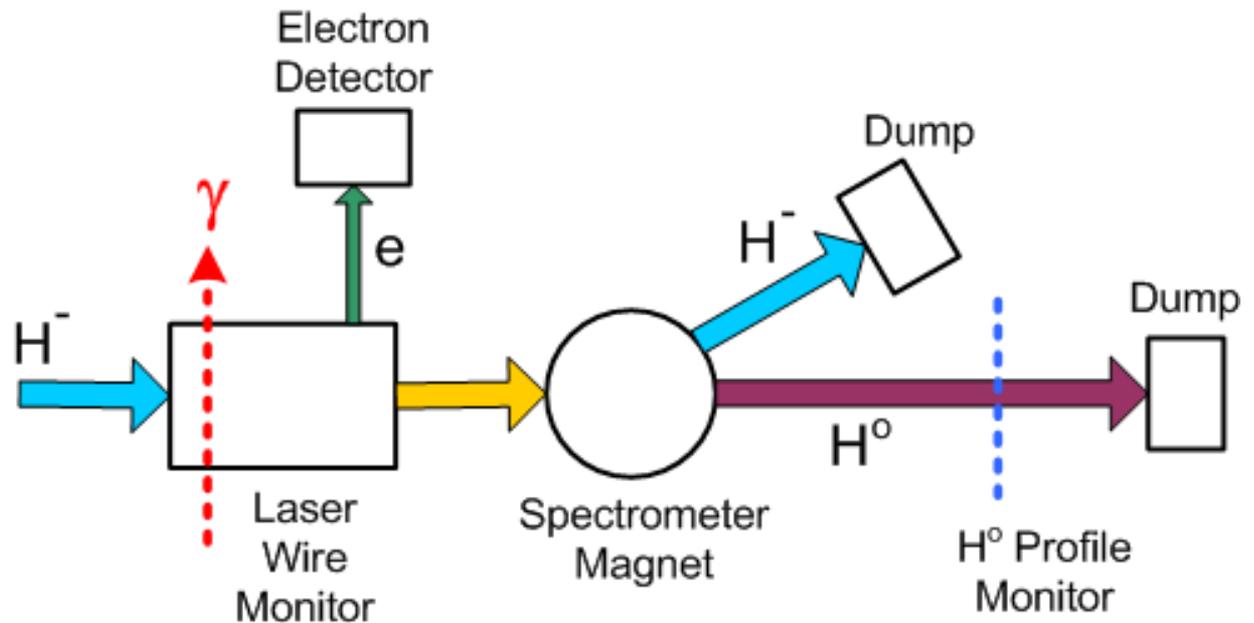


- Project X Collaboration Initiative (November 2008):
 - Present beam instrumentation collaboration projects with SNS, LBNL, and SLAC
- SNS
 - Various advanced diagnostics systems (**broadband Faraday-cup**, e-beam scanner, **MEBT beam instrumentation**, **laser wires**, etc.)
 - Support, information exchange, R&D help, visits, reviews, etc.,
- LBNL
 - **Development of a mode-locked fiber laser system for longitudinal bunch profile measurements (also bunch tails), distribution of laser light with fiber optics**
 - **Byrd & Wilcox – see Wilcox talk this meeting**
 - **Critical to use HINS at testing facility**

Laser Wire Diagnostic Test Station

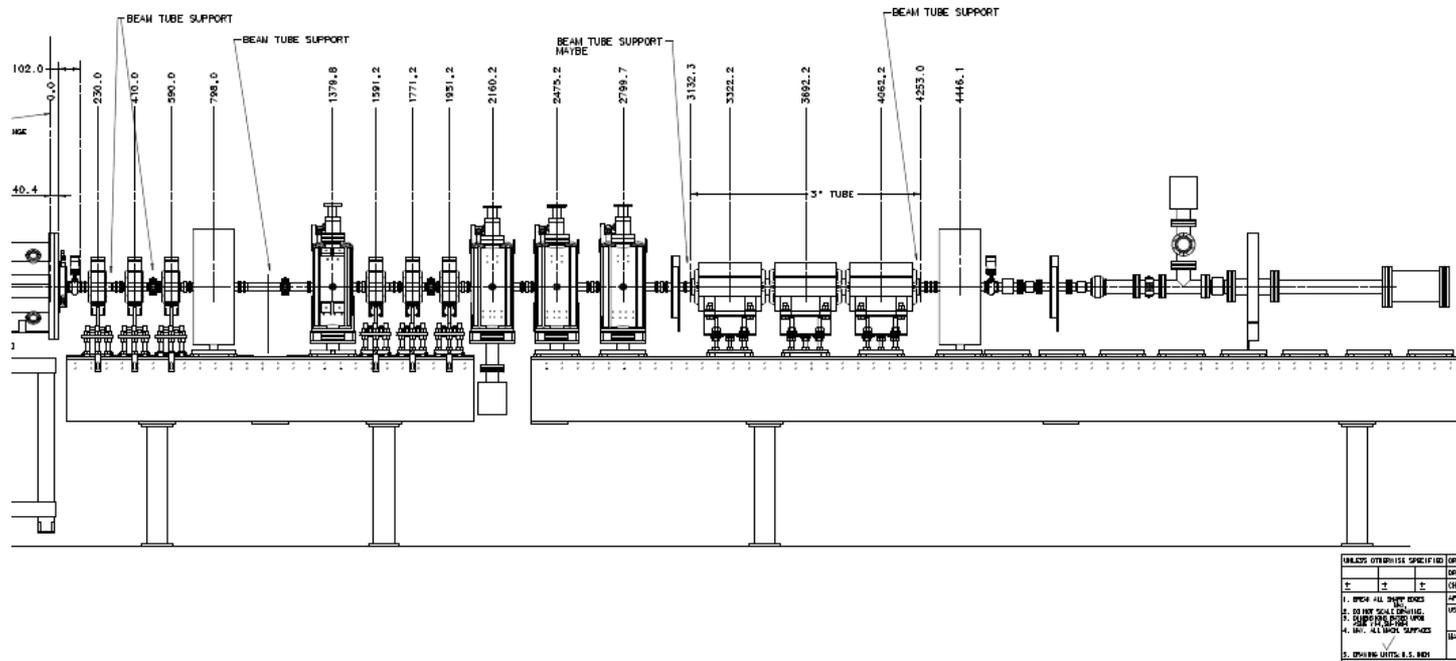


Transverse Beam Profiles using Laser Wire and electron detector



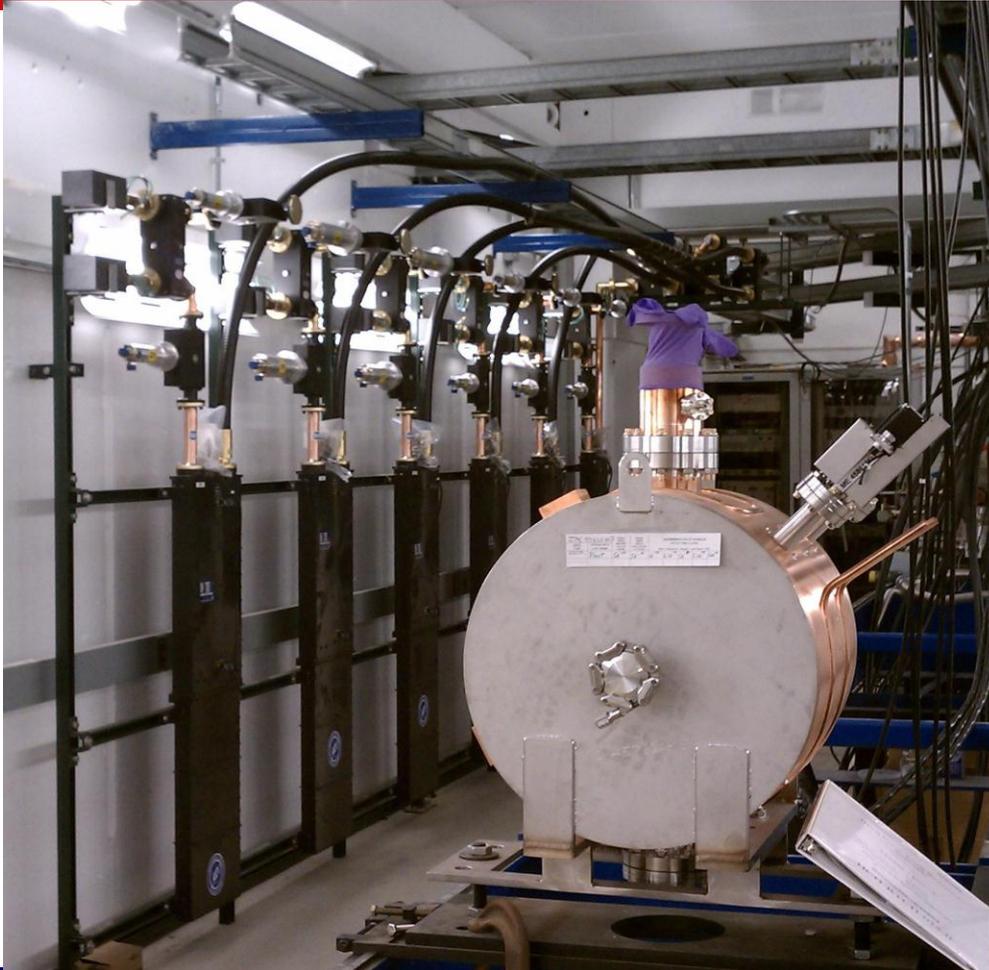
Transverse Emittance using Laser Wire, electron detector and H⁰ profile monitor

MDB Test Facility Six-Cavity Test

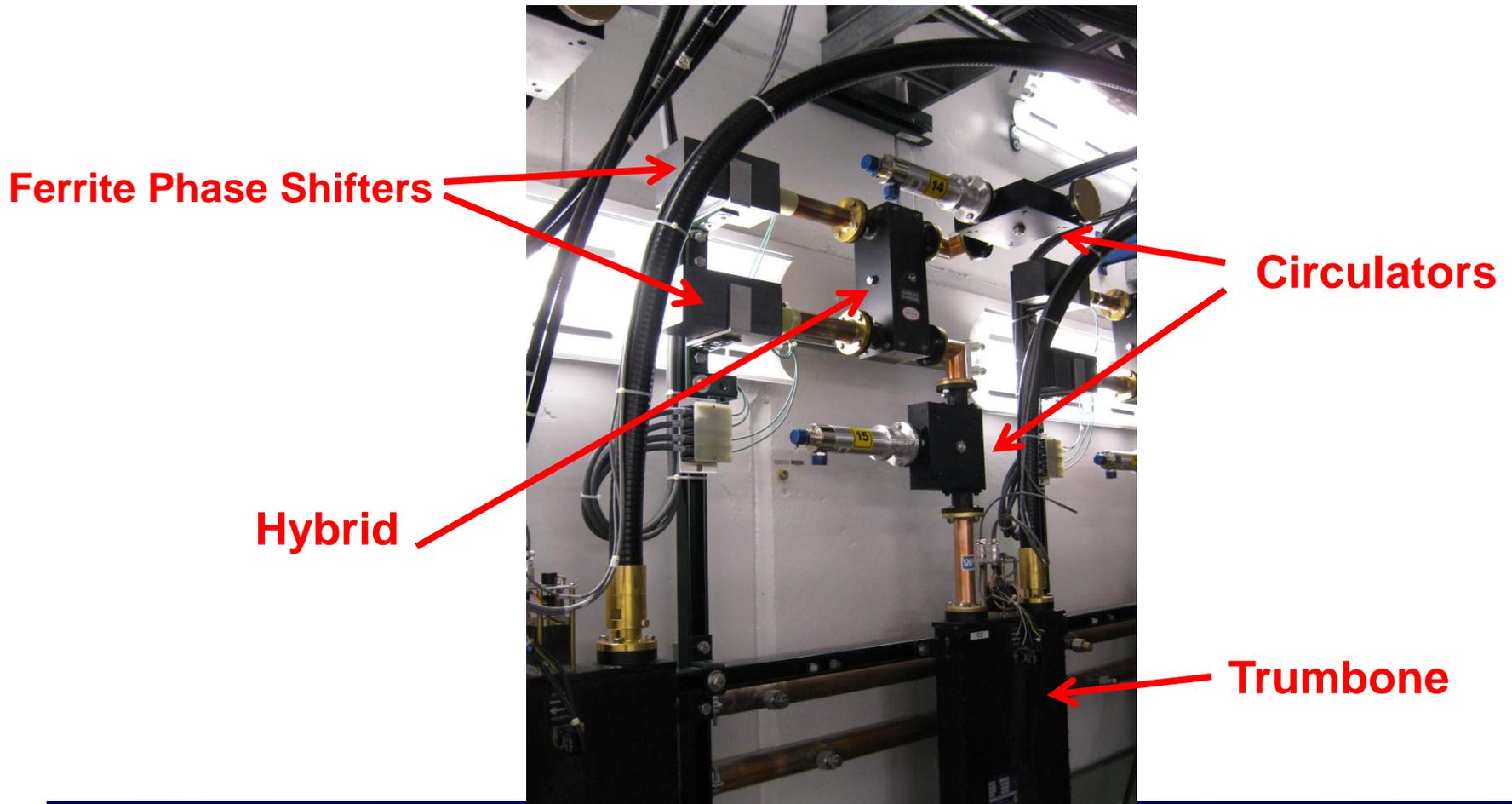


- Demonstrate use of high power RF vector modulators to control multiple RF cavities driven by a single high power klystron
 - Summer 2011

Partial Installation of Six-Cavity Test



RF distribution system
in background and one
RF cavity in foreground
inside HINS beam
enclosure

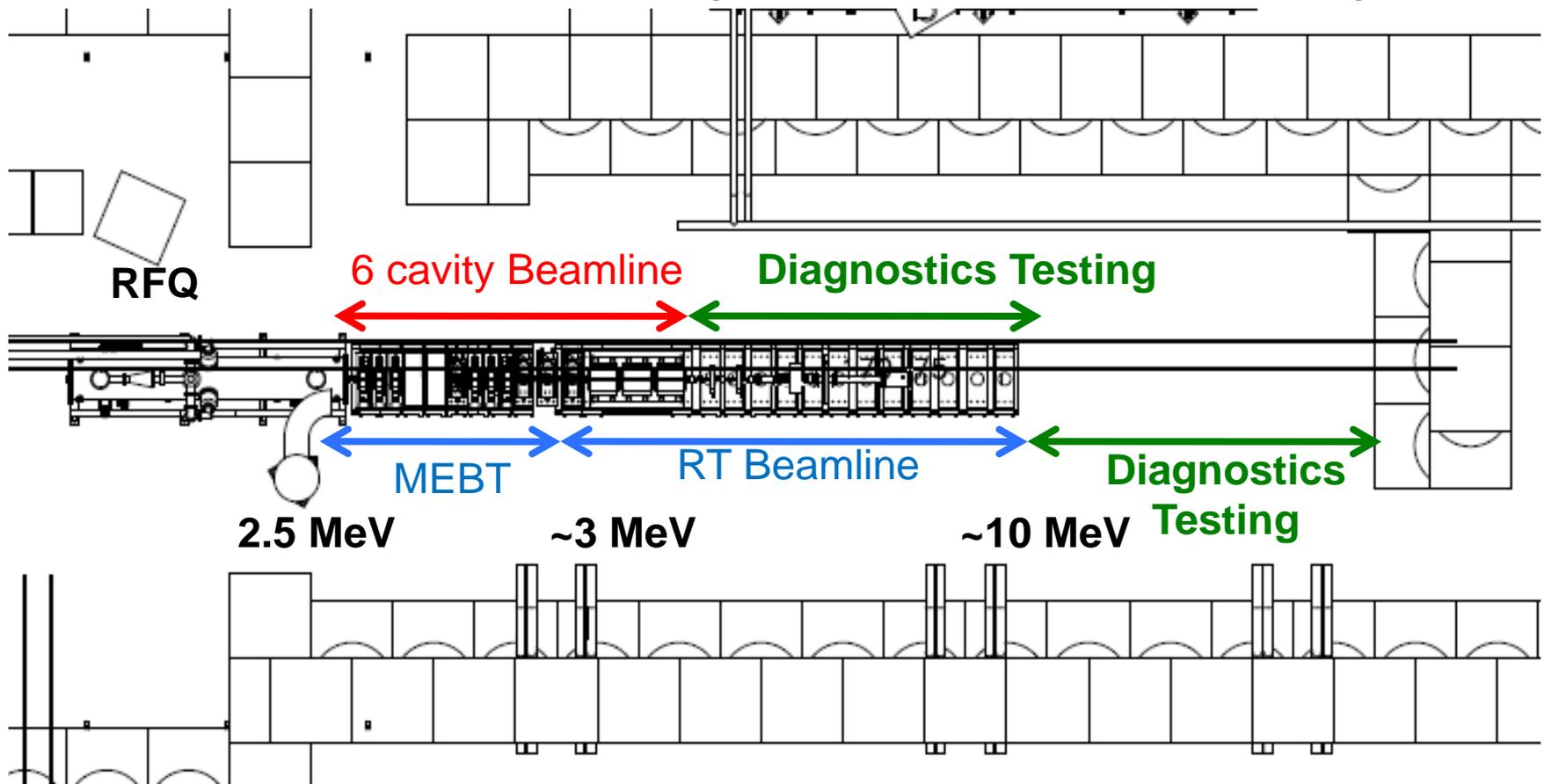




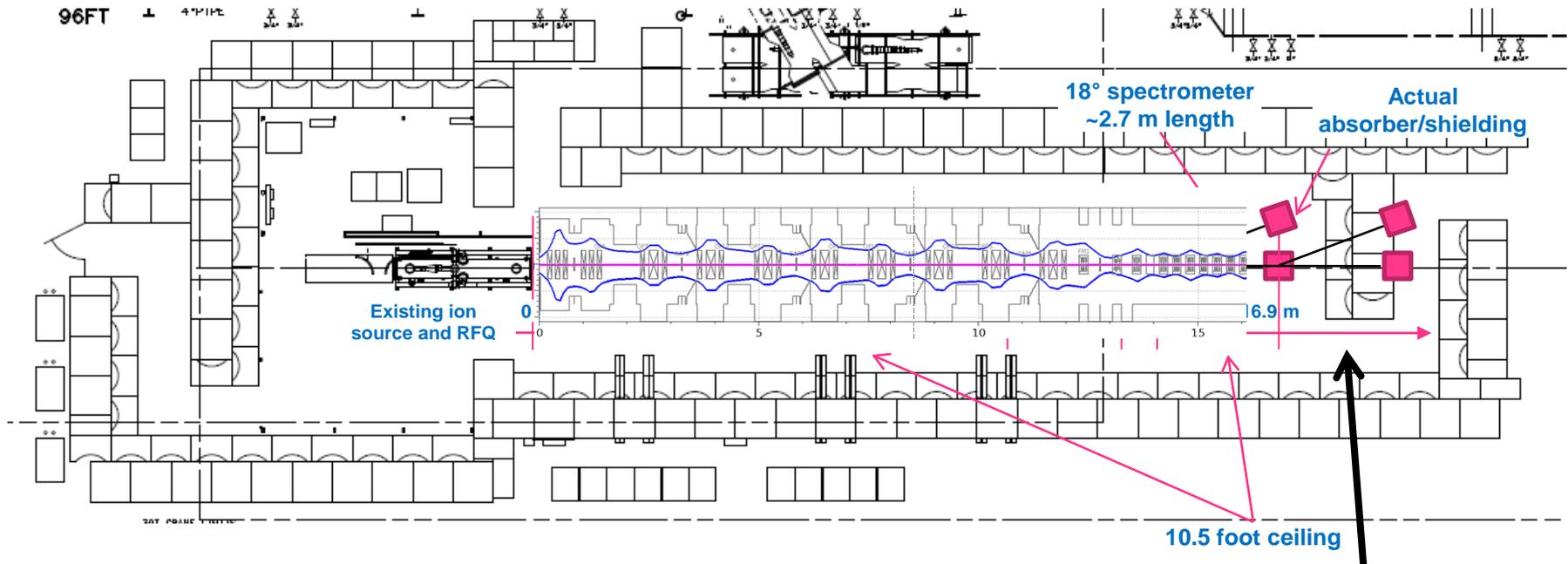
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- FY11
 - Complete Linac enclosure electrical, water, and safety interlock system infrastructure installations
 - Re-commission RFQ with beam
 - Begin Six-Cavity Test beam line installation
 - Install H- source
 - FY12
 - Complete beam line installation
 - Install and commission beam line controls, LLRF, and RF interlocks
 - Commission beam line and commence test plan
 - FY13
 - Successfully complete Six-Cavity vector modulator/beam tests
 - Decommission test set-ups as required
 - Complete final technical papers and reports



HINS beamline will evolve – diagnostics section will adapt to changes



MDB Long Term Plan Chopper and 4-Cavity CM



With cryomodule need
additional 3+ meters cave
length pending spectrometer
line optics design



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- MDB Test Facility (HINS) has taken initial proton source and RFQ beam measurements
 - RFQ has been repaired and reinstalled at MDB
 - New diagnostics line has been installed
 - RFQ Beam measurements to start shortly
 - Six cavity (and H^- source?) to be installed this year
 - *Laser diagnostic projects need H^-*
 - Success with HINS measurements will allow for future Project X front-end testing and characterization at Meson

End